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DURABILITY- KEY FACTOR OF NEW GENERATION CONCRETE PREPARATIONS

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ABSTRACT

Most concretes are excellent at 28 days otherwise a simple repair or replacement may be done. However, concrete is meant to last for decades or centuries. After the first 28 days concrete will continue to mature and age, depending on the original material composition and properties and the environmental actions during service. Sulfates, Chlorides, Acids and Soft water are causing disintegration or expansion. Durability failure may also occur because of internal expansion from concrete constituents that are swelling; usually because of a reaction product absorbing water. This paper focuses different causes and issues related with durability of structural concrete. Hydraulic concrete is one of the most-used construction materials around the world. Portland cement is its principal component, but during its production a lot of energy is needed, and big volumes of greenhouse Gases like CO_2 are released.

KEYWORDS: Durability, Swelling, Soft Water, Structural Concrete, Environmental Action

INTRODUCTION

The concept of 'durability' is difficult to quantify as it may be 'good' or 'better', but such a description has no meaning without a proper definition. Additionally, durability is not a property of a concrete material, or a concrete structure, but it is'behaviour', a performance, of a concrete structure in a certain exposure condition. The technology is improved in such that, it is easy to produce long life concrete but less than 10% of all the concrete currently made is really designed for a long service life, even though the extra cost involved is minimum when compared with the expenditure occurred in future on the maintenance of poorly constructed structural concrete (Christopher C. S., 2005). 'Service life' is a much better concept for describing the durability of concrete. The service life is defined as 'the time during which a concrete fulfils its performance requirements', without non-intended maintenance (Newman J. and Choo B. S, 2003). Consequently, service life is a quantitative concept, with the dimension [years] that can be compared for very different alternative selection of materials or structural design concepts. To be able to define service life, the 'performance' of the concrete must be identified and the performance requirements must be defined. Traditionally, the load-carrying capacity of a concrete structure is taken as the design parameter, but from practice, experience shows that the performance could involve a number of other things, i.e. aesthetics, apparent reliability, lack of visible signs of deterioration, etc. The definition of service life is shown in Figure 1. 'Service life design' (SLD) is based on predictions of future deterioration. To be able to make a design for service life certain information must be available:

- Performance requirements; must be known, relevant and quantified.
- Environmental conditions; decisive parameters must be known, including future changes.

- Deterioration mechanisms; must be known; if not, the prediction methods, test methods and properties will be irrelevant.
- Prediction methods; preferably non-accelerated tests or, better, a theoretical model, decisive material properties and environmental parameters.

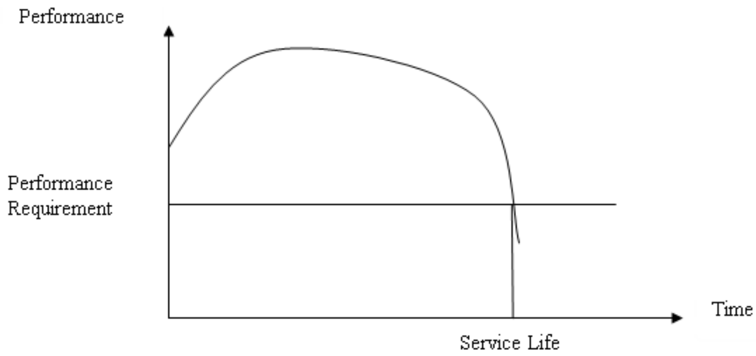

Figure 1: Service Life Definition

Durability of concrete is defined as the ability of concrete to Perform better in the aggressive exposure to which structural concrete is subjected over a long period of time with negligible repair and Maintenance.

MAJOR CHALLANGES (MEHTA P. K. AND MONTERIO P. J. M., 2007)

Challenge I

World Demand/Year

- 11.5 billion ton of concrete
- 1.5 billion ton of cement
- 1 billion ton of water
- 9 billion ton of aggregate
  - 1.5 billion ton of cement generates 1.5 billion ton of CO_2 which is responsible for 5% CO_2 production in the world.
  - 1 billion ton of water equals to 110,000 times of water in bay.
  - 9 billion ton of aggregate depletes the natural resources

Challenge II

Long Term Durability

- Civil Infrastructure quickly deteriorating

The most recent progress involves newly introduced guidelines that will allow for greater use of limestone as interground material in finished cement. This will have no impact on product Performance but will ultimately reduce CO2 by more than 2.5 Mt (2.8 million tons) per year (National Ready Mixed Concrete Association, 2012).

ENVIRONMENTAL RELATED CAUSES OF CONCRETE DURABILITY PROBLEMS

Different types of concrete deterioration may be described by the nature of the attack, whether it is external or internal, and in what environments the attack will occur. The durability characteristics of concrete may be caused by the environment in which the structural concrete is exposed to or by internal causes within the structural concrete.

The following are the durability problems which are related to environmental causes: corrosion of steel, Acid Attack, carbonation, sulphate attack, chloride attack, sea water attack.

Sulphate Attack

Sulphate attack is a chemical breakdown mechanism where sulphate ions attack components of the cement paste. The compounds responsible for sulphate attack are water-soluble sulphate containing salts, such as (calcium, magnesium, sodium, potassium) sulphates that are capable of chemically reacting with components of concrete. It combines with the Calcium silicate hydrate gel or concrete paste, and begins destroying the paste that holds the concrete together. As sulphate dries, new compounds are formed, often called ettringite (Nagesh M., 2012).

The sulphate + hydrated calcium aluminate or the calcium hydroxide components of hardened cement paste + water = ettringite (calcium sulphoaluminate hydrate).

The sulphate + hydrated calcium aluminate or the calcium hydroxide components of hardened cement paste + water is called gypsum (calcium sulphate hydrate).

Acid Attack

The deterioration of Concrete by acids is primarily the result of reaction between these chemicals and Calcium Hydroxide of the hydrated Portland cement. In most cases, the chemical reaction results in the formation of water soluble calcium compounds which are then leached away by aqueous solutions. Mineral acids of all types will have a destructive effect on concrete and the acid attack rate is determined by some factors such as the amount and concentration of acid, the cement content, the type of aggregate used in respect to the its solubility in acids, and of the concrete permiability. When the hydrated cement reacts with an acid, the lime in the cement tends to neutralize the acid. If the concrete is made with a siliceous aggregate, neutralization can only be affected by the breaking down of the cement binder (Nagesh M, 20112).

Carbonation

It is a reaction between the lime in concrete and the carbon dioxide from air, yielding Calcium Carbonate.

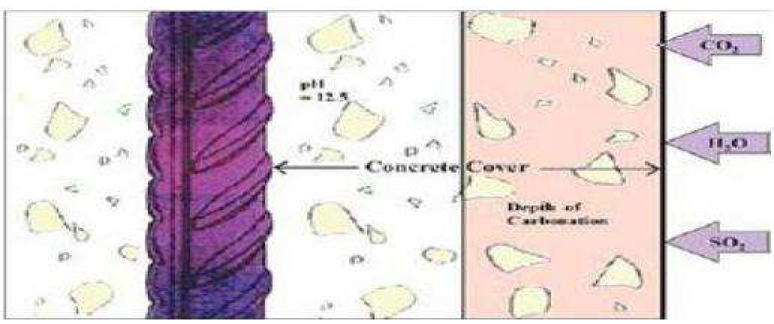

Figure 2: Carbonation of Concrete

It is a process by which CO_2 from the air penetrates into Concrete and reacts with calcium hydroxide to form Calcium carbonates in presence of water.

$$CH + CO_2 \longrightarrow CaCO_3 + WATER$$

This chemical Reaction removes CH which was giving high alkalinity to Concrete. This brings down the pH of the concrete which will accelerate the corrosion of reinforcing steel in concrete. Good concrete and sufficient cover is the main parameter to govern the durability (Nagesh M., 2012).

Chloride Attack

Chloride enters the concrete from Cement, water, aggregates and sometimes from Admixtures. The amount of chloride required for initiating Corrosion is partly dependent on the pH value of the Pore water in concrete. As per is-456-2000 for RCC and PCC embedded metal maximum total acid soluble chloride content expressed as kg/cu.mt. of concrete is 0.6.

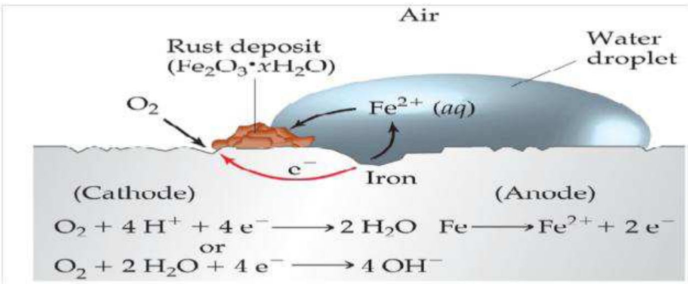

Figure 3: Chloride Attack

Thus chloride attacks the reinforcement rather than Concrete. Nothing happens to concrete in the beginning except the reduction in pH but the reduction in the pH will cause the corrosion of steel which will create durability problem (Nagesh M, 20112).

Sea Water Attack

Concrete in contact with sea water deserves special attention due to many reasons as structures which are very near to costal and offshore area are exposed to the action of a number of cycles of physical and chemical deterioration processes. This situation gives very good opportunity to understand the complexity of durability related problems of concrete in practice.

Most seawater has fairly uniform in chemical composition, which is characterized by the presence of about 5 % soluble salts by weight. The ionic concentrations of sodium and Chloride are the highest, typically 11,000 and 22,000 mg/liter, respectively. However, from the view of aggressive action to cement hydration products, sufficient amounts of Magnesium and Sulfate are present, typically 1500 and 2800 mg/liter, respectively. The pH of seawater varies between 7.4 and 8.5, the average value in equilibrium with the atmospheric Carbon dioxide 8.2. Under exceptional conditions like bays, lagoons, harbors etc. pH values lower than 7.4 may be encountered; these are usually due to a higher concentration of dissolved Carbon dioxide which would make the seawater more aggressive to Portland cement concrete.

Concrete exposed to marine environment may deteriorate due to effects of chemical action of seawater constituents on cement hydration products, alkali aggregate expansion, crystallization pressure of salts within concrete if

one face of the structure is subject to wetting and others to drying conditions, frost action in cold climates, corrosion of steel in RCC or Prestressed members, and physical erosion due to wave action and floating objects. Attack on concrete due to any of these factors will increase the permeability and make the material progressively more susceptible to further action by the same destructive agent but also to other types of attack. Thus a situation of interlocked chemical as well as physical causes of deterioration is found at work when a structural concrete is exposed to seawater is in an advanced stage of degradation.

CONCLUSIONS

Well-designed and well-constructed concrete has a long service life: this is finally evidenced by the number of buildings, bridges, and dams in the world that are still in service in spite of their age. These works prove that concrete is a durable material and that serious deterioration of concrete structures is due either to exceptional events or to exquisitely human factors like the lack of knowledge, technology or negligence. This opinion is strengthened by the fact that over the last sixty years science and technology of materials have developed gradually so that cement and concrete performance has appreciably increased. Therefore, a longer service life of concrete structures depends on concrete durability and other factors like accurate structural and mix design, careful construction process, and diligent maintenance.

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